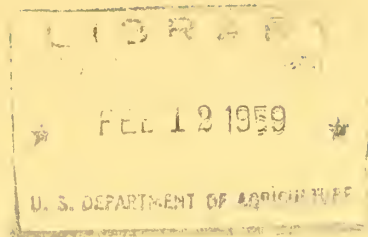


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INFLUENCE of SLASH BURNING

on REGENERATION, OTHER PLANT COVER, and FIRE HAZARD
in the DOUGLAS-FIR REGION

(A PROGRESS REPORT)

by William G. Morris



PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
U. S. DEPT. OF AGRICULTURE • FOREST SERVICE

Owen P. Cramer assisted greatly in this study by performing and supervising the field work in five seasons (1949-53), taking most of the photographs, and preparing the list of scientific names.

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²
William G. Morris

Division of Forest Management Research

^{5c}
July 1958 //

^{7a}
PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION.
R. W. Cowlin, Director ^{5a}Portland, Oregon

⁷U.S. FOREST SERVICE, //

U. S. DEPARTMENT OF AGRICULTURE

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INTRODUCTION

In the Douglas-fir region, is slash burning ultimately good or bad practice?

During the early 1940's whenever a group of foresters met to discuss management or silviculture of that region, they usually debated this question. Until then they had burned slash in most clear cuttings east of the narrow coastal fogbelt as accepted practice. Fire reduced or removed hazardous fuel as required by Oregon and Washington laws. If fire thus sufficiently reduced fuel, State authorities released the landowner from legal liability for maintaining a hazard. According to some foresters, however, slash fires greatly damaged the soil and seedbed surface. They contended that leaving slash and protecting it from accidental fires was better forestry.

Although research in this region had shown several effects of slash burning on certain soils, foresters lacked conclusive tests of these soil effects on regeneration. From analysis of an Olympic clay soil in the Oregon Coast Range in a recent burn, in a burn 2 years old, and in 2 nearby unburned stands, Fowells and Stephenson (6)^{1/} had reported greater quantities of soluble mineral nutrients after burning. According to their conclusions, fire may temporarily increase some soil nutrients, but they warned that repeated burning would exhaust soil organic matter and thus impoverish the soil.

From analysis of a Wind River sandy clay loam in the southern Washington Cascade Range shortly before and after slash burning, Isaac and Hopkins (12) had likewise reported increased available plant food. But they found the following undesirable changes in the mineral soil: (1) Altered structure of the surface soil, (2) less moisture-holding capacity in the 0—3-inch layer, and (3) less organic

^{1/} Underscored numbers in parentheses refer to list of literature cited at end of report.

matter. In their preliminary study, Douglas-fir^{2/} seedlings died when transplanted to spots where heat from several burning logs had reduced surface soil to red ash; seedlings planted nearby on less severely burned spots survived. According to soil analysis at these reddened spots, harmful physical changes had occurred, nitrogen had decreased, and organic matter had disappeared.

Isaac (9) had measured temperatures on soil surfaces blackened like those following a slash fire. In direct sunlight these temperatures greatly exceeded those on normal mineral soil, and Douglas-fir seedlings only a few weeks old usually died from surface heat injury. According to other studies by Isaac (11), number of seedlings per acre on 5 of 7 slash-burned areas 6 to 10 years after logging was less than on unburned spots within the burn. On these 5 areas, however, much seed fell before the slash fire, but scant seed fell afterward. On the two areas where restocking was more abundant on the burned surfaces, scant seed fell before burning but much fell afterward.

Munger and Matthews (17) had reported more conifer seedlings on unburned slash areas. Moreover they observed that hazard gradually decreased on unburned slash areas and abruptly increased on burned areas until it was nearly equal on both at 18 years after cutting.

Over a period of several years, foresters had become accustomed to larger accumulations of unburned slash without consequent large accidental fires. In the late 1930's and early 1940's, partial cutting in many overmature stands removed only the larger or higher quality trees. Since slash fires in many of these stands caused a greater hazard by creating snags from the reserve trees, most such areas were left unburned. Also, during World War 2, military authorities restricted slash fires west of the Cascade Range. Smoke reduces aerial visibility, and fire glow at night might have aided hostile submarines. As a result of these military restrictions, some slash areas remained unburned. In addition, since lack of men during the war caused logging operators to postpone slash burning until circumstances were most favorable, much slash remained unburned each year.

^{2/} Scientific names of all trees, shrubs, and herbs mentioned in this report are listed in the appendix.

As open discussion and debate grew, some foresters became known as "burners" and some as "nonburners." The "nonburners" had decided the hazard was less objectionable than the effects of burning the seedbed. Many other foresters preferred to burn under some but not all conditions.

Lack of sufficient clear evidence showing effects of slash burning on regeneration, and conflicting interpretations of casual observations demanded further study. Adequate knowledge required tests of prevalent combinations of climate, forest type, ground cover, soil, slope, aspect, seed supply, quantity of slash, and severity of burning. Consequently, the study described here was begun.^{3/}

Objectives of the study were:

1. In the next 10 to 15 years, study sufficient plots, within the common range of each important variable mentioned above, to obtain knowledge with which foresters can estimate results of treating a given area in a given way.
2. Establish the approximate relative importance of variables involved and determine which should be studied further.
3. Determine approximate limits within which a variable or combinations of variables should be studied.
4. Provide demonstration areas where a complete history of fire and natural seeding is known. The plan also provided for observing and analyzing effects of burning upon (a) slash hazard and (b) shrubs and herbs that may be either beneficial or detrimental to coniferous seedlings.

Only gross effects of current practices in slash burning were to be studied. Detailed physiological effects of blackening the surface or heating the soil were to be omitted. An associated study of effects on soil was proposed and later carried out (19, 20).

^{3/} Morris, William G. Working plan for a study of the comparative effects on stocking and growth of coniferous reproduction following no burning, light burning, medium burning, and severe burning of logging slash after clear cutting in the Douglas-fir region, 1947. (Unpublished manuscript. Copy on file at Pacific Northwest Forest and Range Experiment Station, U. S. Forest Service, Portland, Oreg.)

Results of plot observations from 1947 to 1953 are described in the following progress report.

METHODS OF STUDY

Establishing Paired Plots

Paired plots were selected for study; one within a logging unit was burned in routine slash disposal by the administrative agency, whereas a replicate within the same unit was left unburned. Selection of paired plots was based on similarity of slash, slope, aspect, soil, seed supply, and original brush conditions. Since only small areas provide this uniformity, each plot was between one-fourth and one-half acre in size; it was rectangular and at least 1.25 chains^{4/} wide.

Although it is generally recognized that any slash burning should be done immediately after cutting to allow prompt restocking and protection against accidental fire, unfavorable weather and an overload of burning work delayed some burning until the next season. Since effects of current practices of slash burning were to be studied, plots scheduled for burning were selected in slash 1 to 18 months old. Thus in two pairs of plots burned at the same time, one pair may have borne tree seedlings or brush and weeds with one season of growth whereas the other bore only new slash. Most plots were burned in fall. About half of the pairs had been logged 6 months or more before burning and could have had regeneration, weeds, and brush at time of burning.

Aided by administrators on national forests from Mt. Rainier south to the South Umpqua River and in the Siuslaw coastal area, we tentatively selected plots wherever there was a likely opportunity to protect a suitable replicate from burning. Since slash disposal money could not be spent to protect the replicate against the adjoining slash fire, its survival depended on roads and cleared strips resulting from logging and on freedom from flying embers. In more than half of the tentative pairs, the fire left too much unburned area on the burned plot or else it destroyed the replicate. Unless two-thirds or more of the burned-plot area was blackened, we rejected it.

When we finally selected a pair of plots, two men permanently marked and mapped the plot corners relative to access routes

^{4/} 1 chain equals 66 feet; 10 square chains equal 1 acre.

and nearby patches of timber or scattered trees of seedbearing size. They recorded location details, cutting and burning dates, topography, soil, site quality, and previous forest cover.

Despite the limited number of places where it was practicable to select potential plots, and despite later losses among selections, 63 pairs were established over a 7-year period, listed here by year of burning:

1946	8
1947	1
1948	15
1949	20
1950	9
1951	9
1952	<u>1</u>
Total	63

Of these pairs, 54 lay in the Cascade Range type of climate, and 9 lay in the climate of the midcoastal part of Oregon (fig. 1). One pair in the eastern foothills of the Coast Range is included with the Cascade Range plots because its climate and vegetation resemble those of the Cascade foothills. Since most of the national-forest logging units scheduled for burning in 1946-52 were in Oregon, most of the plots were established there. Attempts to establish more plots in Washington failed.

Cascade plots were well distributed in an elevation range from 1,400 to 4,200 feet above sea level. Coastal plots were mostly 500 to 800 feet above sea level.

Slope averaged 22 percent on the Cascade plots and 48 percent on the coastal plots. It ranged from 0 to 65 percent in the Cascades and 18 to 80 percent in the coastal area. Three or more pairs of plots lay on each aspect designated by eight equal divisions of the compass, but half of the plots lay in the quadrant from south to west.

Soil on nearly all of the plots had produced vigorous forest growth, as shown by the previous stand. On half of the plots, the surface texture was loam with numerous small concretions locally called "shot." Only one-fourth of the plots had stony or rocky soils and only one-tenth of them had sandy soils. Four feet or more of soil covered nearly all plots.



Figure 1. --Locations of 63 pairs of study plots in relation to some geographical features of western Oregon and western Washington. One of each pair was burned in routine slash disposal; its counterpart was left unburned.

Density of brush in the original stands was estimated according to three classes of the range commonly found in the Douglas-fir region. On the Cascade plots, it was sparse to medium. On the coastal plots, it was medium to dense.

Since most of the plots were on areas logged under a policy of small patch cuttings, they lay within a few chains of a stand of timber of seed-bearing age. However, 8 of the Cascade pairs and 1 of the coastal pairs lay 8 chains or more from standing timber. Several other pairs lay at similar distances from timber stands, but numerous scattered seed trees stood nearby.

Although precise ratings of seed crops during the period of study are unavailable, plot examiners annually estimated the

percentages of trees bearing cones in the vicinity of the plots. From these data we rated relative abundance for the plots as a whole in different years. Abundance differed greatly by localities, especially in years of moderate or less abundance. Douglas-fir crops for the period affecting the seedling records reported here were good in 1949, medium in 1946 and 1950, and poor in 1947 and 1948. Records of western hemlock seed are less reliable because the observations were mostly made from such a distance that the smaller hemlock cones might not have been seen. Hemlock crops were good in 1949, medium in 1946, and poor in 1947, 1948, and 1950. Since crops in 1951 and 1952 had little or no effect on seedling records described later, they are not listed here.

Measuring Fire Effects

In the first growing season after burning, examiners photographed the plots from several permanently marked points, recorded severity of burn or kind of surface cover along five lines across each burned plot, and recorded kind of surface cover on each unburned plot. To do this, the examiners randomly located a line lengthwise within each of five equal bands across the narrow dimension of a plot. (Since the minimum plot width was 1.25 chains, the 5 lines totaled at least 6.25 chains or 412.5 feet in length.) Then they stretched a tape, graduated in chains and links (0.66-foot), along the line and recorded the data link by link.

From previous observations of severity of burn by wildfires four distinct classes were defined^{5/} for this study as follows:

1. Unburned.
2. Light burn (figs. 2 and 3)--duff, crumbled rotten wood, or other woody debris partly burned but not down to mineral soil; or, where these were absent before the fire, logs not deeply charred.
3. Moderate burn (fig. 4)--the foregoing materials consumed; or, where these were absent, logs deeply charred, but the mineral soil under the ash not changed in color.
4. Severe burn (fig. 5)--a top layer of mineral soil changed in color, usually to reddish; often the next half inch is blackened from organic matter charred by heat conducted through the top layer of soil.

^{5/} See footnote 3, page 3.



Figure 2. --In the "light burn" class, fire leaves an organic cover of scorched duff, rotten wood, and sound wood on the mineral soil.



Figure 3. --Five days after a slash fire, ash covered this area of lightly burned duff. When the ash was removed, as in the foreground spot, unburned needles of the duff layer appeared.



Figure 4. --In the "moderate burn" class, fire consumes the duff but does not discolor the mineral soil.



Figure 5. --In the "severe burn" class, fire consumes the duff and discolours the mineral soil. The foreground area just left of center burned severely.

Surface cover recorded on unburned or lightly burned spots included: mineral soil, duff, crumbled rotten wood such as is commonly found in uncut stands, wood (in the form of bark, small chunks, and limb wood), branches with adequate fine twigs to make appreciable shade for seedlings, stubs or crowns of live brush, dense stands of herbs, logs, and stumps. More than one kind of material could be recorded for the same spot. Wood or rotten wood covering more than 90 percent of the ground was separately designated.

Annually or biennially through 1953, plot examiners recorded the following on each pair of plots:

1. Number of advance and postlogging conifer seedlings 6 inches or more in height found on 100 sample milacres of each plot. The milacres were quadrants of 4-milacre circles 7.45 feet in radius. An examiner located five circles in each of five rows across the plot by a system of restricted random placement resembling that of the sampling lines described above. He tallied seedlings in each milacre by 4-milacre clusters.

2. Number of current-year conifer seedlings on strips of mineral soil near the plots and along the nearest timber edge.

3. Proportion of total number of nearby mature trees bearing cones.

4. Ocular estimate of the proportion of ground covered by crowns of brush on each milacre used for recording tree seedlings.

5. On each milacre used for recording seedlings, the proportion of total brush cover contributed by each species composing one-fifth or more of the canopy.

6. Herbaceous plants, as for items "4" and "5."

7. Photographs from the original points.

8. Fire hazard in terms of expected rate-of-spread class and resistance-to-control class. The examiner estimated the class of speed at which a fire would spread across each quarter of a 1-chain-square area during average bad August fire weather. The four classes had relative speeds of 1:5:25:125. He also estimated the class of resistance to control along a fireline built by hand by the easiest route across the 1-chain-square area. These classes had

relative amounts of control work represented by 1:2:4:8. The product of the rate of spread and resistance to control gives an index number representing amount of control work created per hour by a potential fire. Such index numbers for the small samples were later averaged for the entire burned or unburned plot.

RESULTS--BURNED VS. UNBURNED PLOTS

Fuels and Other Cover Soon after Burning

Quantities of several classes of fuel found on line samples of burned and unburned plots in the first summer after the slash fire appear in table 1. Patches of wood, bark, large limbs, and crumbled

Table 1. -- Average quantities of several classes of material on line samples of burned and unburned paired plots^{1/} in the first season after slash fire

(Percentage of line samples) ^{2/}		
Item	: Burned	: Unburned
Chunks of wood and bark, large limbs, or crumbled rotten wood covering more than 90 percent of the ground	10	25
Chunks of wood and bark, large limbs, or crumbled rotten wood covering less than 90 percent of the ground	38	35
Branches resting above the ground and bearing adequate fine twigs to make appreciable shade for seedlings	1	23
Logs larger than 11 inches in diameter	12	13
Live crowns of brush	3	12
Dense stand of herbs	11	15
Mineral soil	50	22

^{1/} Basis: 59 pairs; 4 pairs not established until the second season after the burn are omitted because a year of plant growth partially obliterates surface conditions on a burn.

^{2/} Since some classes of material were not mutually exclusive, average percentages total more than 100.

rotten wood almost completely hiding the ground covered a fourth of the line sample of unburned plots. Douglas-fir seedlings seldom germinate and survive in such patches but hemlock often survives on crumbled rotten wood. On burned plots, these patches (fig. 6) covered much less of the sample. The class of such materials hiding less than 90 percent of the ground covered about equal proportions of burned and unburned plots. Proportions of the sample covered by both classes of fuel totaled 60 percent on the unburned plots and 48 percent on the burned.

Branches supported above the ground and having adequate twigs to cast appreciable shade (fig. 7) covered almost a fourth of the sample on unburned plots but scarcely occurred on the burned plots. Logs over 11 inches in diameter covered about 12 percent of the sample on both burned and unburned plots. Quantities of materials on individual plots differed greatly from the averages; for most averages, about 10 percent of the plot quantities were two times or more greater.

Interpretation of the percentages showed that burning did the following: (1) Eliminated practically all branches bearing fine twigs; (2) reduced size of some spots in which sound wood, rotten wood, and other fuels almost completely covered the ground and probably thinned out fuels on others so that they fell in the class covering less than 90 percent of the ground; (3) eliminated some spots of wood, rotten wood, and other fuels covering less than 90 percent of the ground; (4) charred but did not appreciably reduce volume of logs larger than 11 inches in diameter (fig. 8).

In the first summer after burning, few crowns of brush survived on burned plots, but they covered 12 percent of the area of unburned plots. In contrast, herbs formed a dense stand on 11 percent of the area of burned plots and on only a slightly greater part of the unburned plots.

Ground surface in which mineral soil made up a large or exclusive component appeared on 50 percent of the line sample of burned plots but on less than half as much of the unburned plots. The excess area on burned plots resulted from burning of duff, sound wood, and rotten wood overlying mineral soil. Field measurements did not include spots of mineral soil smaller than about 1 foot along the line sample. Hence the true total areas of mineral soil would slightly exceed the recorded areas.

As found by other tabulations, quantities of materials on coastal plots differed from quantities on Cascade plots. Quantities of



Figure 6. --In some patches, chunks of wood, bark, large limbs, or crumbled rotten wood covered more than 90 percent of the ground.



Figure 7. --Branches with sufficient twigs to cast appreciable shade covered 23 percent of the sample on unburned plots.



Figure 8. --A slash fire only slightly reduces volume of most large logs that are separated. Despite this remaining volume of fuel, future fires will burn less intensely because small woody debris is lacking to help develop a hot sustained fire between the separated log faces.

brush, herbs, and wood partly covering the ground were clearly larger on coastal plots. Quantities of mineral soil after burning and quantities of logs were larger on Cascade plots.

Severity of Burning

Fire-blackened logs and ground gave a devastated appearance to many cutting units. Where logging had not destroyed the duff layer, uncharred duff lay below most of the black surface. If slash burns as soon as the fine fuels have sufficiently dried to carry fire, either in spring after winter rains or in fall after soaking rains, the fire produces small amounts of severely burned ground. The deeper moist duff does not burn even though a normal collection of branches and fresh litter burns hotly above it.

As shown by averages of the line samples (table 2) less than 6 percent of the ground on Cascade plots and only a trace on coastal plots burned severely. Severely burned ground on different plots

ranged from 0 to 31 percent. Less than a fifth of the Cascade plots burned severely on 10 percent of the surface. Considering that any plot was rejected if the fire did not blacken two-thirds of the surface, this small quantity of severe burning is noteworthy. On most plots, the ground burned severely only in small scattered patches. These patches usually appeared beneath large, deeply charred logs, or beside deeply charred stumps, or in spots where parts of logs had completely burned while lying on the ground.

Table 2. -- Percentage of ground in each of four classes^{1/} of severity of burn on Cascade and coastal plots

Location	: Severe : : burn :	: Moderate : : burn :	: Light : : burn :	: Unburned :
Cascade Range (50 pairs of plots) ^{2/}	5.8	22.2	55.4	16.6
Coastal strip (9 pairs of plots)	0.1	14.2	75.2	10.5

^{1/} Defined page 7.

^{2/} Four pairs of plots not classified until the second season after the burn are omitted because experience showed a year of weathering and plant growth partly obliterates characteristics that distinguish classes of burning severity.

More than half of the ground burned lightly, and a layer of crumbled duff, rotten wood, or other woody debris remained. In the early 1940's, according to Aufderheide and Morris (1), a newly adopted policy resulted in much lightly burned area. Instead of burning summer-dried slash just before an early fall rain was expected, fire control men burned it after the duff was soaked and as soon after rain as fine fuels had sufficiently dried to carry fire.

Although a surface layer of duff, crumbled rotten wood, or other woody debris may benefit soil, it may also hinder reseeding. This layer protects soil from erosion, supplies some soil organic matter, and prevents deterioration of top soil by heat of the slash fire. But it keeps seeds from reaching a better germinating bed of mineral soil and aggravates severe temperature conditions for

seedlings. Seeds of western hemlock, being smaller, penetrate the organic layer better than those of Douglas-fir or the Abies, and are more likely to reach suitable germinating conditions. Since wood and dead leaves (or needles) conduct heat more slowly than mineral soil, heat does not rapidly move from the sun-heated surface to cooler lower levels in daytime or from the warm lower levels to the cooling surface at night. Hence surface temperatures of the organic layer compared to those of mineral soil will rise higher in daytime and fall lower at night. Daytime temperatures may cook the stems of tender seedlings, and nighttime temperatures may freeze them. Moreover, a fire-blackened surface reaches greater extremes of heating and cooling than a lighter surface.

Severity of burn and fuel characteristics on a plot did not necessarily represent the surrounding logging unit. Since we selected slash that would carry fire across two-thirds of the ground, some plots may have contained more slash than average for the surrounding tract. Likewise, some may have burned more completely and more severely than the surrounding tract. Although not always representing the average of the surrounding tract, a pair of plots equal in slash gave a reliable comparison of the effects of burning and not burning.

Restocking by Conifer Seedlings

At a given time after the slash fire, stocking by conifer seedlings established after logging differed little between burned and unburned (table 3) plots. In the Cascades, although stocking on unburned plots slightly exceeded that on burned plots through the fifth growing season, it differed significantly^{6/} only in the third season. In the coastal strip, neither of the two differences in available records was significant.

Although data in table 3 show the overall effect of customary slash burning compared to nonburning, a precise comparison of the single effect of burned vs. unburned ground surfaces would require equal exposure to seeding and weathering. To obtain such a comparison, slash must be burned immediately after logging. In table 3, about half of the plots represented in the column for 3 growing seasons were

^{6/} In this report, significance of differences was determined from a "t" test of mean differences between paired plots. The term "significant" is used for the 0.05 level, and "highly significant" for the 0.01 level.

logged in the early spring, winter, or calendar year before burning. On the unburned plots, a crop of seed shortly before or soon after logging may have produced surviving seedlings, whereas on the burned plots most of the seed or seedlings may have burned in the delayed fire. Therefore, we retabulated the seedling tallies to compare stocking a given number of growing seasons after burning and the same number of seasons after logging (table 4). Tallies to provide a column for a seventh growing season were lacking.

Table 3. -- Average stocking established after logging, on burned and unburned plots, ^{1/} by number of growing seasons ^{2/} after a slash fire

(Percentage of stocked 4-milacre quadrats)

Location and treatment	Number of growing seasons			
	3	4	5	7
Cascade Range:				
Burned	14	21	28	60
Unburned	23*	25	36	57
Coastal strip:				
Burned	49	91	--	--
Unburned	57	84	--	--

^{1/} Numbers of pairs of plots for the 3rd, 4th, 5th, and 7th seasons respectively are: Cascade Range--30, 18, 21, 8; Coastal strip--8, 3.

^{2/} Increase in stocking with time cannot be accurately estimated by reading across the table because, for example, some plots represented in the column for 3 growing seasons are not represented in other columns.

* Indicates a statistically significant difference between burned and unburned.

Table 4. -- Average stocking established after logging, on burned and unburned plots, ^{1/} by number of growing seasons^{2/} after slash burning on burned plots and after logging on unburned plots

(Percentage of stocked 4-milacre quadrats)

Location and treatment	Number of growing seasons		
	3	4	5
Cascade Range:			
Burned	14	22	29
Unburned	19	21	34
Coastal strip:			
Burned	44	88	--
Unburned	40	55	--

^{1/} Numbers of pairs of plots for the 3rd, 4th, and 5th seasons respectively are: Cascade Range--33, 20, 19; Coastal strip--9, 4.

^{2/} See footnote 2, table 3.

None of the stocking percentages in table 4 for burned compared to unburned plots in a given geographic area and season differed significantly. Owing to a small number of plots and inconsistent differences for individual pairs of plots, even the large average difference for coastal plots in the fourth season was not significant. Hence, the differences suggested by table 3, which represent effect of some delay in burning, decreased when adjusted to show probable results under a practice of burning all areas in the first fall after logging. To reduce the period of high fire hazard and to hasten restocking, forest managers usually prefer to burn as soon as possible after logging, but unfavorable weather sometimes prevents burning in the first season.

Seedlings obviously established before logging were tallied separately and were omitted from these comparisons. Species were

mostly western hemlock, grand fir, and Pacific silver fir. Many showed logging injuries and signs of severe suppression. If included, they would increase the values in tables 3 and 4 about 1 unit for burned plots and about 10 units for unburned plots. If advanced seedlings were included, effects of burning would have to be determined separately for original stands having different densities of such seedlings. Since this stand characteristic differs greatly, adequate sampling would require many more plots than were practicable in the present study.

Since the averages for 3 growing seasons (tables 3 and 4) include many plots established too recently to be included in the averages for 4 or more seasons, the reader can only roughly estimate change in stocking with increasing time. If the older plots were exposed to more abundant seed and to more favorable weather after seeds germinated, their stocking would exceed that of the younger plots.

Apparently the average Cascade plot restocked slowly with postlogging seedlings. Records for individual plots showed that in the third season less than a fifth of them had reached the "medium" stocking class.^{7/} Table 3 suggests that the average plot did not reach this class until about the sixth or seventh season. Stocking of seedlings 6 inches or more in height, as recorded in this study, will be somewhat less than if the common practice had been followed in which a healthy seedling that has survived 1 growing season is included regardless of height. Since a large proportion of these surviving the first season die in the second season (9), the common practice probably gives an overestimate of seedlings that will survive several years.

On coastal plots, the few available records indicated "medium" stocking by the third season and "good" stocking by the fourth season or soon after. In table 3, stocking on these plots significantly exceeded that on similarly treated Cascade plots for the same number of growing seasons. In table 4, stocking on burned coastal plots significantly exceeded that on burned Cascade plots, but on unburned plots the smaller difference lacked significance.

^{7/} Stocking classes are those customarily used in Oregon and Washington, in which percentage of 4-milacre plots stocked with one or more established seedlings is grouped in the following categories: nonstocked, 0-9 percent; poor stocking, 10-39 percent; medium stocking, 40-69 percent; good stocking, 70-100 percent.

More prompt restocking in the coastal area was probably partly due to a greater proportion of western hemlock in the nearby stand and a more favorable climate. Possible reasons for more seedlings from a hemlock reserve stand than from a Douglas-fir or Abies stand are: (1) The longer crowns of hemlock produce more seeds, (2) the smaller seeds fly farther, and (3) seed-eating rodents miss a larger proportion of small seeds in debris on the ground. The cooler and more moist coastal climate, moreover, enables more seedlings to survive.

Bever (3) reported greater stocking of Douglas-fir and no difference in stocking of hemlock on burned as compared to unburned plots 1 to 6 years after logging. He tallied seedlings on 19 tracts of 160 acres each in several counties surrounding the Willamette Valley. In contrast, Lavender and associates (14) found that stocking of both Douglas-fir and hemlock on unburned plots exceeded stocking on burned plots 4 to 11 years after logging. They tallied seedlings on 13 settings of 18 to 140 acres, mostly in the west-central parts of the Oregon Cascades.

Owing to differences in sampling methods, results of those studies cannot be directly compared with results given here. In those studies, samples were taken at regular intervals in tracts of burned slash, and 1-milacre or 4-milacre spots were classified as burned or unburned; then average stocking for all burned spots was compared with average stocking for all unburned spots. In most burned tracts, many spots with one or more of the following characteristics remain unburned: (1) All fuel scraped away to mineral soil, (2) a layer of duff and thin litter across which fire did not spread soon after a rain, (3) rocky soil with scant litter, and (4) wet ground. Such spots do not represent the average of an entirely unburned tract. In the present study, we compared average stocking throughout one-fourth acre or more of unburned slash with that on a similar adjacent area at least two-thirds blackened by fire. These samples thus represent conditions after entire tracts are either left unburned or are well covered by fire.

Another difference between methods of the present study and those of Bever and Lavender is likely to affect results. When they classified ground as burned or unburned, most of the tract had been burned at least several years before, and more than half of those in Lavender's study had burned 6 years or more previously. He mentioned the difficulty in estimating degree of burn long after a fire. In the present study, field crews established nearly all plots in the first growing season after the fire and re-examined them in successive

years. By the second season, many lightly burned spots of duff weathered to an appearance difficult to distinguish from that of unburned duff.

Effects of other factors on restocking.--Since Douglas-fir may bear little or no seed in several successive years, number of seedlings established during a given period of years depends on coincidence of seed crops. Seed may have been plentiful in one locality and scarce in another in a given year; but, for the period as a whole represented by seedlings in tables 3 and 4, the supply probably equaled or exceeded the normal.

Despite abundant crops of cones on uncut trees near some plots in certain years, large numbers of seedlings did not necessarily follow during the next summer on the cutting unit. On strips of mineral soil 1/10 chain wide and 1 or 2 chains long beneath or beside the timber edge, examiners counted current-year seedlings as an index of potential regeneration close to the timber. They also counted seedlings on strips of mineral soil close to the plots as an index of potential regeneration at that distance from the seed source. Seedling numbers decreased greatly at distances of only 3 or 4 chains from the timber. Since 1 pair of plots 12 chains from seed restocked nearly as well as a comparable pair 2 chains from seed, distance did not always control stocking.

Garman (7) and Isaac (11) likewise found sharply decreased quantities of seed and seedlings as distance from timber increased, but some other investigators did not. From an isolated patch of timber on a ridge top, Dick (4) obtained similar seed distribution on the windward side of prevailing strong winds; but on the leeward side he caught the most at 4 chains distance and caught less at 1 chain and at 7 chains or more. Lavender and associates (14) stated that "rate of restocking of an area is reduced only slightly with increase in distance from seed source." Their tables show more stocking in a narrow border close to the seed source, but beyond that border--to the limit of their data at 15 chains--they show no decrease with distance. Their cutting units were mostly 40 to 140 acres. After studying cutting units of 160 acres or more, Bever (3) showed a difference in stocking at distances of one-fourth and one-half mile from adjacent timber.

In the present study, though current-year seedlings equivalent to 4,000 to 8,000 per acre often grew just inside or at the timber edge, less than 2,000 per acre usually grew close to the plots. Since

counts close to the plots were restricted to unburned mineral soil that was usually loose and favorable for seed germination, many less seedlings would be expected over the average area of the plots. Examiners usually tallied seedlings after the initial high rate of mortality that occurs with the first high surface temperatures following emergence.

At the timber edge, examiners often found a far greater proportion of current-year hemlock seedlings than at a point several chains into the cutting unit. Shade during part of the day at the timber edge probably caused this difference in proportions of hemlock.

Aspect, slope, soil, and density of brush showed no distinct effect on stocking of individual pairs of plots. Other studies (3, 11, 14) in this region have clearly shown better stocking on northerly aspects. Evidently many more than 30 pairs of plots would be necessary to identify and determine relative effect of such factors on seedlings under field conditions sampled here.

On unburned Cascade plots, number of seedlings on exposed mineral soil exceeded the number on other surface materials. Seedlings on mineral soil also grew well (fig. 9). Records for the most recent examination showed whether the seedlings were growing on exposed mineral soil or whether the soil was covered with duff, rotten wood, or other woody debris. Examiners made such records wherever there were sufficient seedlings to indicate relative preference for a mineral soil surface; 17 pairs of Cascade plots and 5 pairs of coastal plots gave these records. On the unburned Cascade plots, 49 percent of the seedlings grew where mineral soil was exposed. Since mineral soil covered only 25 percent of the plot surface when the plots were established, percentage of seedlings on this material was twice as great as would be expected if surface had no influence. This apparent favorable effect of mineral soil was statistically highly significant.

On the 17 burned Cascade plots, examiners found 64 percent of the seedlings growing on mineral soil. When they classified the plot surfaces soon after burning, 53 percent of the average plot area was mineral soil from which either logging or burning had removed the covering organic layer. Although these figures indicated a greater concentration of seedlings on the surface having no organic cover, the concentration lacked statistical significance. In tallying seedlings, examiners did not segregate those found on soil exposed by logging and those on soil exposed by burning. We cannot, therefore, compare the quality of these two seedbeds.



Figure 9. --In the fourth growing season, Douglas-fir seedlings showed unusually great height on bare mineral soil of this plot.

On both unburned and burned coastal plots, seedlings did not grow more densely on mineral soil. Here seedlings were mostly western hemlock and Sitka spruce as contrasted to mostly Douglas-fir in the Cascades.

Important factors of regeneration not measured in this study are loss of seed to rodents and birds and loss of seedlings caused by rodents, high surface temperatures, and drought. These probably contributed to inconsistencies in stocking not readily explained by the records. Good cone crops near many of the plots in fall, contrasted with few seedlings growing the next summer, indicated that rodents and weather destroyed many seeds and seedlings. Hooven (8) and Moore (16) have shown that rodents eat large quantities of tree seeds in patch cuttings like those studied here.

According to Isaac's (9) studies of survival of Douglas-fir seedlings, heat at the soil surface in spring and early summer kills a large percentage.

Brush and Herb Cover

Average quantities of brush (shrub) canopy on unburned plots exceeded those on burned plots (table 5). These quantities were ocular estimates of proportion of ground covered by a vertical projection of crowns on each of the 100-milacre subplots per large plot. Even though some differences lacked statistical significance, all averages for unburned plots exceeded corresponding averages for burned plots. Unburned coastal plots produced more brush than unburned Cascade plots. The average percentage of ground covered by crowns on both the coastal and Cascade plots may seem too small. When looking across many such cutover areas, an observer receives a visual impression of almost continuous brush. This erroneous impression arises because intervening brush hides the open spaces.

Table 5. -- Average quantities of brush cover on burned and unburned plots, ^{1/} by number of growing seasons after a slash fire
(Percentage of ground covered by crowns)

Location and treatment	Number of growing seasons				
	2	3	4	5	7
Cascade Range:					
Burned	4	9	10	11	18
Unburned	9*	14*	16	22*	24
Coastal strip:					
Burned	6	13	19	6	--
Unburned	19*	25*	28	30	--

^{1/} Numbers of pairs of plots for the 2nd, 3rd, 4th, 5th, and 7th seasons, respectively, are: Cascade Range--48, 36, 24, 23, 8; Coastal strip--9, 8, 3, 2.

* Indicates a statistically significant difference between burned and unburned.

Comparison of successive seasons cannot properly be made in table 5 because, owing to differences in time of establishment, columns for some seasons include certain plots but not others. Individual plot records, however, showed that brush quantity increased very little on either the burned or unburned plots during the fourth to seventh seasons. Isaac (10) reported similar observations on 15 areas in western Oregon and western Washington.

Differences in average quantity of herb cover on burned and unburned plots lacked statistical significance (table 6). Examiners recorded average quantity of herb cover independently of the brush, but estimated it in the same manner on the same milacre samples. Quantities on the coastal plots exceeded those on the Cascade plots. As before, adjacent columns in this table do not properly show herb density in successive years. Individual plot records on the average show little change in quantity after the third season. This corresponds with Isaac's (10) observations.

Table 6. -- Average quantities of herbaceous plant cover on burned and unburned plots, ^{1/} by number of growing seasons after a slash fire

(Percentage of ground covered by crowns)

Location and treatment	Number of growing seasons					
	2	3	4	5	7	
Cascade Range:						
Burned	15	23	31	26	31	
Unburned	14	22	35	29	42	
Coastal strip:						
Burned	23	31	48	45	--	
Unburned	27	34	45	40	--	

^{1/} Number of pairs of plots for the 2nd, 3rd, 4th, 5th, and 7th seasons, respectively, were: Cascade Range--50, 36, 24, 23, 8; Coastal strip--9, 8, 3, 2.

During the first few years after a slash fire, herbaceous plants appeared unable to grow on the larger patches of severely burned soil. In contrast, they quickly covered adjacent areas that were moderately or lightly burned (fig. 10).

If brush and herb records were tabulated to compare quantities for a given time since burning and an equal time since logging the unburned plot, as described for table 4, quantities for the unburned plots in tables 5 and 6 would be slightly less.

Relative Quantities of Individual Brush Species

We studied the quantities of individual brush species during the third to fifth seasons after the slash fire to identify noteworthy differences between burned and unburned plots, between Cascade and coastal plots, and between different numbers of years since burning. For each milacre plot, field records gave the proportion of total brush cover contributed by each species composing one-fifth or more of the canopy. Although we could not determine effects on stocking, we compared the relative quantities of several species because experience indicates that some species--e.g., snowbrush ceanothus--are a greater fire hazard and some species--e.g., salmonberry--are a greater physical barrier to conifer reproduction than are other species producing the same quantity of crown cover.

In proportion of total brush cover for the third to fifth seasons after burning, vine maple ranked first more frequently than any other shrub on either burned or unburned Cascade plots (fig. 11). It also grew in significant proportions (defined for descriptive purposes as 15 percent or more of the total brush cover) on two-thirds of the plots. This occurrence surpassed that of all other species. Where it became a significant proportion of the brush, it usually did so by the second season after burning. With few exceptions, it covered a greater actual area on unburned than on burned plots.

For Cascade unburned plots, Pacific rhododendron predominated in proportion of brush cover on more plots (25 percent) than any other species except vine maple. For burned plots, on the other hand, it ranked lower than snowbrush ceanothus. Rhododendron and vine maple were prominent in the forest before logging, but ceanothus was not. Rhododendron usually became a significant proportion of the brush by the second season after the slash fire. On a few plots it became a significant proportion of the brush on the burned plot alone.

When a log burned almost completely, it produced a patch of severe burn within an area of light burn viewed July 1 following the fall slash fire.



On August 1, 2 years later, herbs and shrubs were growing well on the light burn, but almost none had started on the severe burn.

After another year, a few plants were growing on the severe burn, and trailing blackberry, rooted on the perimeter, had begun to cover the ground.



Figure 10.



Figure 11. --Vine maple predominated in the shrub cover on Cascade plots, and it covered more of the unburned than of the burned area. This view shows vine maple in the foreground on an unburned plot in the fourth season after logging.

For Cascade burned plots, snowbrush ceanothus predominated in proportion of brush cover on more plots (25 percent) than any other species except vine maple. On only two pairs did it grow in significant proportion on the unburned plot. Most of it grew between the South Umpqua and North Santiam drainages. It first attained a significant proportion in the second season after burning on 5 plots (fig. 12); in the third season, on 7; and in the fourth season, on 3. It did not grow in adjacent uncut stands and apparently started from seed that had lain dormant for many years until stimulated by the slash fire. This response to fire is frequently observed (21, p. B47). Except for one pair, total density of brush on a burned plot dominated by ceanothus did not surpass that on its unburned counterpart where one or more other species formed the brush cover.

Relative quantities of the three foregoing shrubs compared to that of salal and Oregongrape exceeded that reported by Isaac (10). Since most of his plots lay at lower elevations, we should expect a difference in species.

A burned plot in the
first season after burning. ➡



➡ In the second season,
snowbrush ceanothus covered
the ground.

No ceanothus grew
on the adjacent un-
burned plot (second season). ➡



Figure 12.

Relative quantities of other species in the Cascades did not approach those of vine maple, rhododendron, or ceanothus. For burned plots, whitebark raspberry (blackcap), blueberry elder, and golden chinkapin^{8/} each predominated on several plots and ovalleaf whortleberry (blue huckleberry), western thimbleberry, and Pacific dogwood each prevailed on one plot. For unburned plots, whitebark raspberry and salal each prevailed on several plots, and blueberry elder, ovalleaf whortleberry, western thimbleberry, and Pacific yew each prevailed on 1 or 2 plots. For burned and unburned plots combined, Oregongrape, bigleaf maple, winter (redflowering) currant, bitter cherry, red whortleberry (huckleberry), baldhip rose, and common snowberry ranked second on 1 or 2 plots each. About half of the above species seldom grew in the forest before logging.

On the 8 pairs of coastal plots with records for the third to fifth seasons, western thimbleberry prevailed over other species on 5 of the burned plots and 2 of the unburned plots. Salmonberry prevailed on 3 of the unburned and 1 of the burned plots. Salal, red whortleberry, and Pacific red elder prevailed on only 1 or 2 plots. All except elder grew abundantly in the forest before logging.

Relative Quantities of Individual Herb Species

In proportion of total herbaceous cover recorded during the third to fifth seasons after burning, fireweed (perennial) ranked first on 40 percent of either the burned or unburned Cascade plots. It predominated more frequently than any other herb. Trailing blackberry^{9/} predominated on about 30 percent of either the burned or unburned plots. Despite predominance on a large proportion of the plots, each species failed to establish itself in a significant quantity (15 percent or more of the total herbaceous cover) on either plot in 30 percent of the remaining pairs. Wherever these species did grow in significant quantities, they usually appeared in the second season after the slash fire. On the coastal plots, fireweed and blackberry seldom grew in significant proportions.

^{8/} Although golden chinkapin, Pacific dogwood, Pacific yew, bigleaf maple, and bitter cherry are tree species, they are noncommercial species on these plots. In size and effect they were comparable to brush species and were recorded as brush.

^{9/} Trailing blackberry and modest whipplea, although botanically not herbs, were included in the herbaceous records. Like most herbs, they are part of the lowest ground cover, whereas most shrubs form a much higher cover.

Although woodland groundsel (senecio) made up the principal herbaceous cover on burned surfaces in the second growing season on 34 percent of the Cascade plots, it abruptly decreased to a minor species in the third season (fig. 13). By then, it prevailed on only 8 percent of the burned plots and comprised a significant proportion of the cover on only 18 percent. On unburned surfaces it grew less densely than on the burned. Its principal range was between the Clackamas and North Umpqua drainages, and it was not recorded in significant quantities on the coastal plots.

Autumn willowweed (annual fireweed), another transient of the plant community, predominated on several burned and unburned plots in the Cascades in the third season but did not grow in significant quantities before or after that.

American twinflower ranked first on several unburned plots in the Cascades and ranked second on 25 percent of all the plots. On the adjoining burned plots, it ranked first on none and second on only 6 percent. In the Cascades, it alone among herbaceous plants continued in large quantities from the uncut forest.

Modest whipplea ranked first or second on 13 percent of the Cascade burned plots and on 9 percent of the unburned plots. All of these lay south of the McKenzie drainage.

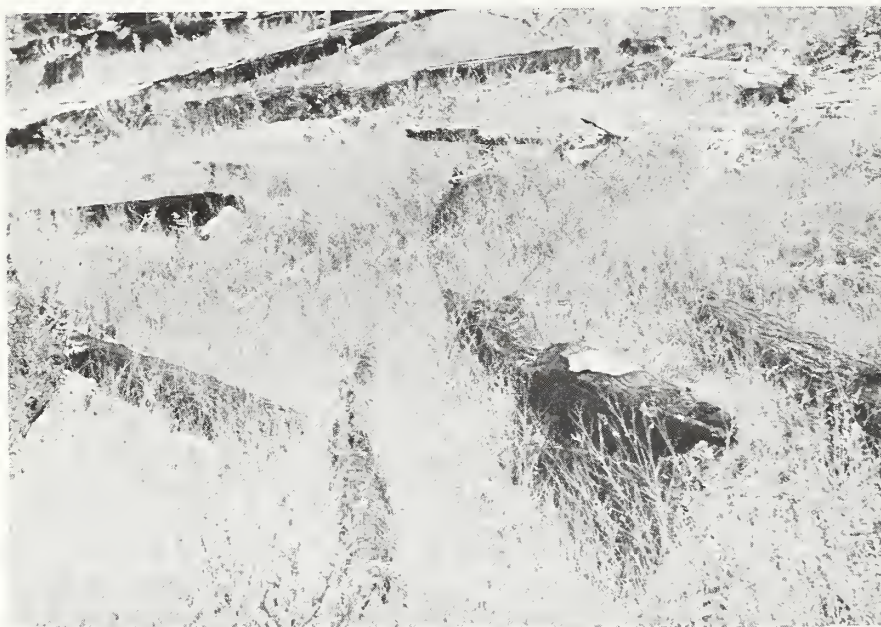
Western bracken predominated in sparse herbaceous cover on one pair of plots at Wind River and made up a significant proportion of the herbaceous cover for only one other pair of plots in the Cascades.

Other species that ranked first or second on one to several Cascade plots were: bull thistle, sedge, halberd-leaved morning-glory, peavine, big deervetch, prickly lettuce, coast penstemon, betony (hedgenettle), lupine, Scouler's campanula, grass, Oregon oxalis, and bunchberry dogwood. The last two grew prominently in some stands before logging.

On the coastal plots, only western swordfern predominated on several plots (fig. 14). It grew conspicuously in the original forest and survived more frequently on the unburned than on the burned plots. Other species that ranked first or second on 1 or 2 plots were western bracken, fireweed, Australian burnweed, Oregon oxalis (prominent before logging), western common pearleverlasting, woodland phacelia, sedge, and trailing blackberry.



No plant growth (1st season)

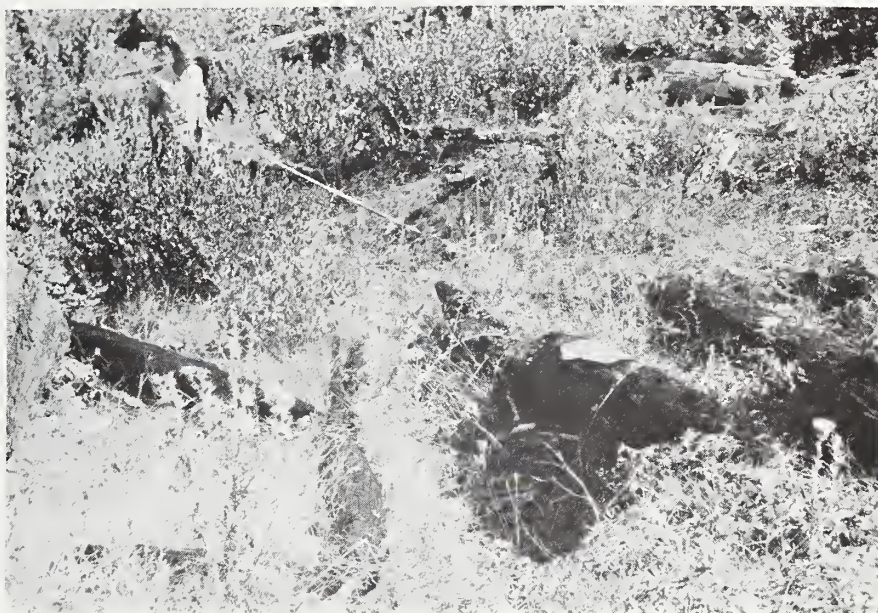


No groundsel but dense autumn willowweed (3rd season)

Figure 13.--The same area showed much change in



Dense woodland groundsel (2nd season)



Little willowweed but some bull thistle, trailing blackberry, lupine, and snowbrush ceanothus (4th season)
plant cover in four successive seasons after burning.



Figure 14. -- On the coastal plots, plant cover grew more densely than on the Cascade plots, and western swordfern predominated in the herbaceous class as shown here in the third growing season after burning.

Fire Hazard Ratings

Burning reduced expected rate of spread 50 percent or more for 7 seasons and reduced resistance to control one-third or more for 5 and possibly 7 seasons, as shown in table 7. Cascade and coastal plots were combined in this table because they were similar in terms of hazard. Except for resistance to control in the seventh season, based on only eight pairs of plots, each numerical rating for unburned plots significantly exceeds that for burned plots.

Although rate of spread appears to have changed with time since the slash fire (table 7), there actually was no change. Data in the table may mislead the reader because the same plots did not provide records for each number of seasons. Owing to the small number of plots having records for five or more successive seasons, the change with time lacked significance. These trends are, nevertheless the best available estimates. According to table 7, rate of spread in unburned slash 4 or 5 seasons after the normal time of slash burning had decreased to about half of that in the first season. In the meantime, rate of spread on burned areas increased twofold.

Resistance to control ratings (table 7) changed little or not at all up to the seventh year. Individual plot records likewise showed this lack of change.

According to general observations, rate of spread on burned plots falls below that on unburned plots, mostly because slash fires

Table 7. -- Averages of expected rate of spread and resistance to control on burned and unburned plots, by number of growing seasons after a slash fire

(Index numbers)

Item	Number of growing seasons					
	1	2	3	4	5	7
Rate of spread:						
Burned	1.1	1.3	2.5	1.7	2.4	2.5
Unburned	20.5	11.2	12.5	7.8	9.0	5.8
Resistance to control:						
Burned	1.8	1.7	1.9	1.5	1.8	1.6
Unburned	3.2	2.8	2.8	3.1	2.7	^{1/} 3.2
Number of pairs of plots	58	49	40	23	21	8

^{1/} Not a statistically significant difference.

consume the smaller slash materials (figs. 15 and 16). Moreover, slash fires increase the space between surfaces of logs and chunks lying in potentially hot burning bunches (fig. 8). Owing to the removal of fine fuels and separation of log surfaces, logs will burn less intensely and for shorter times in any future fire. Less intense fires in a given fuel spread slower.

As time passes, some factors increase rate of spread, whereas others decrease it on both burned and unburned areas. On burned areas, charred wood surfaces weather away and become more easily ignited. On unburned areas, branches and logs slough off bark; similarly, surfaces of sound wood weather, check, fray, rot, and become more easily ignited. At the same time the smaller twigs and branches fall to the ground, form a more compact fuel, and rot away. New growth gradually develops. A canopy of green herbs and brush shields low-lying fuels from sun and wind and helps reduce rate of spread. For the August conditions assumed in this study,



Figure 15. --A late October slash fire beginning to burn a deep layer of tree-top material that hides a few large logs and other debris (upper). Three hours later at the same spot, a moderate burn with little remaining hazard is found (lower).



Figure 16. --On these adjacent plots in the same logging unit, burning reduced the hazard from "extreme" on the unburned plot (upper) to "low" on the burned plot (lower). Fire consumed fine fuels, burned logs in two, and widened spaces between adjacent fuel parts.

such a canopy covering great quantities of unburned slash (fig. 17) reduces rate-of-spread class proportionately more than the small quantity of extra fuel increases it. But for months when herbs and leaves of deciduous brush are dead, rate of spread in a slash, herb, and brush mixture exceeds that in slash alone. For August conditions, dense herbs covering well-burned slash, in contrast, usually increase the easily ignited fuel and rate of spread proportionately more than their canopy reduces it (fig. 18).

Slash burning decreases resistance to control in several ways. Although a slash fire of light or moderate severity only slightly reduces volume of large logs, many burn in two where they cross (fig. 19). This division into shorter lengths facilitates fire-line construction, and logs flat on the ground instead of in a criss-crossed pile will burn less intensely. Burning other parts of slash likewise reduces intensity of future fires. Reducing intensity of a fire in the Douglas-fir region reduces resistance to control, because (1) spotting ahead becomes less troublesome, (2) a narrower fireline is needed, and (3) men can work with less difficulty close to the fire. Removing small logs, tangled branches, heaps of broken wood, and layers of crumbled rotten wood facilitates fireline construction.

Resistance to control, like rate of spread, changes with time. As crossed poles and small logs break into shorter lengths, resistance to control decreases. As brush, vines, and perennial herbs grow, resistance increases. On areas having a low resistance, this change in cover may increase the rating by a considerable proportion, but on areas having a high resistance (fig. 20), the proportion of increase will probably be small.

DISCUSSION

Since average plot data do not clearly indicate the effects of slash burning on establishment of seedlings, a forester who must decide whether to burn a given area may wish to consider known detailed effects of fire on soil. Some earlier studies of these effects were mentioned in the Introduction. In a later study of effects of slash fires on several soils of the Douglas-fir region, Tarrant (19) found beneficial, neutral, and harmful effects on soil and seedlings. In the 0-3-inch layer of lightly burned areas about 1 year after the fire, total nitrogen, phosphorus, and exchangeable potassium exceeded that for unburned areas; cation exchange capacity showed no effect. In such samples of severely burned areas, cation exchange and total nitrogen fell below that for unburned areas, but available



Figure 17. --By protecting slash from summer sun and wind in the fifth season after cutting, a dense cover of fireweed (upper) has somewhat reduced probable rate of fire spread compared to that in the first summer at the same spot (lower). In months when fireweed is dead, it increases rate of spread.



Figure 18. --By the fifth season after burning slash (upper), fireweed has added sufficient dead leaves and stems to increase probable rate of fire spread compared with that in the second season (lower).



Figure 19. --Although most logs 11 inches or larger in diameter do not burn completely in slash fires of light or moderate severity, many logs burn in two where they cross. This shortening will facilitate fire-line construction in case of future accidental fires.



Figure 20. --Large cull logs and chunks cause an extreme resistance to control of a fire.

phosphorus and exchangeable potassium greatly exceeded that for unburned. Although temporarily higher pH--especially after severe burning--and less mycorrhizae occurred at burned spots, net effects of these conditions are not definitely known. The pH did not affect germination, but greater damping off accompanied higher pH. Light burning tended to increase percolation rate in the 0--3-inch layer of two soils, but severe burning greatly reduced it.

We planned to compare rate of growth by seedlings on each class of severity of burn, but, owing to lack of sufficient seedlings, these comparisons became impracticable. In the associated studies by Tarrant and Wright (20), both 1- and 2-year-old Douglas-fir trees on a sandy clay loam had grown equally well on unburned, lightly burned, and severely burned soil. On a clay loam, 1-year-old seedlings on severely burned spots and 2-year-olds on lightly burned spots grew taller than on unburned spots.

Austin and Baisinger (2) in studying slash fires likewise found that moderately to severely burned spots showed harmful, neutral, and beneficial effects on chemical and physical properties of soils. Measurements at the 0--2-inch level 2 years after moderate or severe burns in two locations of one county and four locations of another were averaged and compared with those for unburned areas. Burned spots showed (1) lower moisture equivalent (moisture-holding capacity); (2) slightly less organic matter and total nitrogen; (3) higher pH; (4) about the same available phosphorus, potassium, and magnesium; (5) more calcium. Measurements soon after the fire and at other depths gave different relations.

On three clear-cut and burned units in the Coast Range of Oregon, Dyrness, Youngberg, and Ruth (5) measured several soil properties that indicate erodibility. The soils included a loam and two clays. Erodibility on lightly burned spots of the loam and clays did not significantly exceed that on unburned spots. In contrast, erodibility on severely burned spots of the clay did significantly exceed that on unburned spots; on severely burned spots of the loam, only one erodibility property exceeded that on unburned spots.

Soil studies have not yet provided sufficient information from which the forester can predict net benefit or loss to the regenerating stand if he burns slash on any given soil. Severe burning, as defined here, harms several properties of certain soil types, but light burning harms some of these properties much less and actually benefits others. We do not know effects on other soils. According to plots

in the present study, fires set when the lower duff is moist and the surface is dry will severely burn only 6 percent or less of the ground. Forest managers should, therefore, be principally concerned not with effects of severe burning but with those of light and moderate burning.

Since nearly all plots in the present study were in over-mature stands, volume of logging slash greatly exceeded that from young or thrifty mature stands. Because stems of many trees in overmature stands contain mostly rotten logs, harvesting leaves many logs on the ground. When taller trees fall, more of each stem shatters and adds to the slash. Unlike limbs of younger trees, thicker limbs of overmature trees do not grind into the soil or lie flat on the ground; instead, they add to the hazard of coarse fuels. More decaying windfalls and great heaps of rotten wood in the virgin stand increase slash. In the future, when stands of smaller, thriftier trees form the prevailing crop, slash hazard will decrease, and many logging units may not require burning to give an acceptable hazard. If utilization improves, hazard will further decrease.

When deciding whether to burn slash, the forest manager should consider risks not included in this study. In some localities, either lightning or people may ignite slash when weather is most unfavorable for fire suppression. Then fire may spread to adjoining merchantable timber or restocked young stands. By burning slash during favorable weather and with adequate force under correct procedures, a manager can greatly reduce danger of uncontrolled fires. But even during weather favorable for burning a sudden change of wind or fuel moisture may spread fire beyond the slash area. Either leaving or burning slash entails risk.

SUMMARY

Stocking of coniferous seedlings (commercial species) established after logging and 6 inches or more in height did not differ significantly on plots of burned and unburned slash in the part of the Douglas-fir region that was studied.

In the Cascades, such seedlings did not attain the "medium" stocking class until about the sixth or seventh growing season after the slash fire.

On burned plots, stocking in the coastal area significantly exceeded that in the Cascades. On unburned plots stocking in the coastal area was likewise greater than in the Cascades, but the difference was not statistically significant.

The few available coastal plots reached "medium" stocking by the third year and "good" stocking by the fourth year or soon thereafter.

On unburned Cascade plots, the number of postlogging seedlings growing on patches of exposed mineral soil exceeded that on equal areas of other surface materials. On coastal plots, seedlings grew with equal frequency on either class of seedbed.

Ground surface in which mineral soil made up a large or exclusive component appeared on 50 percent of the area of burned plots but on less than half as much of the unburned plots.

Although we selected burned plots where slash fires had blackened most of the surface, only 6 percent of the ground on Cascade plots burned severely, and only 22 percent burned moderately, according to the classification used. In the coastal strip only 0.1 percent burned severely and 14 percent burned moderately.

Quantities of several classes of fuel left on burned compared to unburned plots showed that burning: (1) Eliminated practically all branches bearing fine twigs; (2) reduced size of spots in which wood, rotten wood, and other fuels almost completely covered the ground and thinned out fuels on other such spots; (3) eliminated some spots of lesser concentration of fuel; (4) charred but did not appreciably reduce volume of logs over 11 inches diameter. Many logs did, however, burn in two where they crossed, and this shortening and rearrangement reduced hazard.

Brush (shrub) crowns covered a greater part of unburned than of burned ground for at least 5 to 7 years after burning. In the Cascades in the fifth season, the crowns covered about 10 percent of the ground on the average burned plot and about 20 percent on the unburned plot. They increased slowly after the third season following burning. In the coastal area they covered more ground than in the Cascades.

Herb foliage covered about the same proportion of area on burned and unburned ground. In the Cascades, herbs covered about 30 percent of the area by the fourth season and changed little in the next few seasons. In the coastal area they covered a greater percentage of the ground.

Vine maple and Pacific rhododendron grew more densely on unburned ground, but snowbrush ceanothus grew more densely on burned ground. Species composition of brush cover differed on Cascade and coastal plots.

In the Cascades, the perennial fireweed and trailing blackberry predominated in the herbaceous cover on a large proportion of the pairs of plots and showed no preference for either burned or unburned ground. Woodland groundsel on burned ground and autumn willowweed on either burned or unburned ground sometimes predominated one year but nearly disappeared the next.

In the coastal area, western swordfern from the original forest cover predominated in the herbaceous cover on several plots and appeared more frequently on unburned than on burned ground.

Estimated rate of spread and resistance to control for a fire on unburned plots exceeded that on burned plots for five seasons or more after the slash fire.

From results of this study to date, we conclude the following: Although burning slash on most patch cuttings similar to those studied does not decisively reduce or increase numbers of postlogging seedlings, it does facilitate fire control.

APPENDIX

Common and scientific names of plants mentioned in the text follow. Those included in "Check List of Trees of the United States" (15) are named accordingly. Others are named according to "Standardized Plant Names" (13), except that three species of herbs not listed by that authority are named according to "A Manual of the Higher Plants of Oregon" (18) and are designated by an asterisk. Common names not often used by foresters in Oregon and Washington have a more widely used name in parentheses.

Commercial coniferous trees

Douglas-fir	<i>Pseudotsuga menziesii</i>
Western hemlock	<i>Tsuga heterophylla</i>
Grand fir	<i>Abies grandis</i>
Pacific silver fir	<i>Abies amabilis</i>
Sitka spruce	<i>Picea sitchensis</i>

Plants mentioned as part of the herb cover

Trailing blackberry	Rubus macropetalus
Fireweed	Epilobium angustifolium
American twinflower	Linnaea borealis <u>var.</u> americana
Willowweed (annual fireweed)	Epilobium paniculatum (autumn w.) and several broadleaf spp. of Epilobium
Modest whipplea	Whipplea modesta
Bull thistle	Cirsium lanceolatum
Western swordfern	Polystichum munitum
Western bracken	Pteridium aquilinum <u>var.</u> pubescens
Deerfern	Blechnum spicant
Australian burnweed	Erechtites prenanthoides
Oregon oxalis	Oxalis oregana
Western common pearlever- lasting	Anaphalis margaritacea <u>var.</u> occidentalis
Betony (hedgenettle)	Stachys spp.
Moss	Musci class
Woodland groundsel (senecio)	Senecio sylvaticus
Bunchberry dogwood	Cornus canadensis
Sedge	Carex spp.
*Halberd-leaved morning-glory	Convolvulus atriplicifolius
Peavine	Lathyrus spp.
Big deervetch	Lotus crassifolius
Prickly lettuce	Lactuca serriola
Coast penstemon	Penstemon diffusus
Lupine	Lupinus spp.
*Scouler's campanula	Campanula scouleri
*Woodland phacelia	Phacelia nemoralis
Grass	Gramineae family

Plants mentioned as part of the brush cover

Vine maple	Acer circinatum
Pacific rhododendron	Rhododendron macrophyllum
Snowbrush ceanothus	Ceanothus velutinus
Whitebark raspberry (blackcap)	Rubus leucodermis
Blueberry elder	Sambucus glauca
Pacific red elder	Sambucus callicarpa
Oregongrape	Mahonia aquifolium
Western thimbleberry	Rubus parviflorus
Salmonberry	Rubus spectabilis

Salal	Gaultheria shallon
Red whortleberry (huckleberry)	Vaccinium parvifolium
Ovalleaf whortleberry (blue huckleberry)	Vaccinium ovalifolium
Golden chinkapin	Castanopsis chrysophylla
Pacific dogwood	Cornus nuttallii
Pacific yew	Taxus brevifolia
Bigleaf maple	Acer macrophyllum
Winter (redflowering) currant	Ribes sanguineum
Bitter cherry	Prunus emarginata
Baldhip rose	Rosa gymnocarpa
Common snowberry	Symphoricarpos albus

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